

Analysis of Labor Variability for Automated Letter and Flat Sorting

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September 2020

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I. Introduction

The Postal Regulatory Commission's (Commission) accepted cost methodology for sorting and other mail processing operations assumes constant returns to scale and/or density, or "100 percent volume variability" in postal costing jargon, for most mail processing activities. That is, the Commission applies a unit elasticity of sorting cost with respect to mail volume for mail processing, apart from selected activities (e.g., time mail processing employees spend waiting for mail) that are classified as non-volume-variable. For the operations that are the subject of this analysis, the associated mail processing costs were taken to be 99.1 percent volume variable in FY 2019 under the Commission's accepted methodology.

The determination of 100 percent and zero percent volume-variable activities is not the result of an empirical analysis of the cost structure of the activities. Rather, the traditional basis was a general assumption that mail processing costs should vary in proportion with the volume of mail or number of articles processed. However, as a matter of theory, the factor(s) of proportionality between mail processing volumes and costs need not be unit cost elasticities, nor need they be the same for mail processing operations with distinct technological characteristics. Over the course of the R97-1, R2000-1, and R2006-1 rate cases, empirical mail processing variabilities based on analysis of Postal Service operating data were extensively litigated, though the Postal Rate Commission ultimately declined to adopt empirical mail processing variabilities citing an array of data quality and methodological issues.

This report revisits the issue of measuring volume variability factors for automated letter and flat processing operations using data from the period after the enactment of the Postal Accountability and Enhancement Act (PAEA). The most recent published studies on the subject (Fenster et al. 2008, Bozzo 2009) used data predating PAEA. Neither paper's results supported the unit elasticity assumption, with Fenster et al. 2008 finding elasticities greater than 1—hence diseconomies of density—while Bozzo 2009 found elasticities mostly less than 1.

Changes in mail volumes, Postal Service cost structure, and data availability since the last studies of PRA-era data merit a reassessment of the evidence on mail processing volume variability. The late-2006 enactment of PAEA roughly coincided with the volume peak for traditional mail in the United States. Annual piece volume for letter- and flat-shape mail in the "market dominant" First-Class Mail, USPS Marketing Mail (previously Standard Mail), and Periodicals—products primarily comprised of letter- and flat-shaped mail—fell by nearly a third, from 207 billion pieces in FY2007 to 136 billion pieces in FY2019. In the course of these large and sustained volume declines, U.S. Postal Service (USPS) operations have seen similarly substantial changes. Over the same period, the annual labor cost for letter and flat processing operations in USPS mail processing plants fell 36 percent from \$4.44 billion to \$2.86 billion in nominal terms, or 44 percent adjusted for growth in per-hour mail processing labor costs.

While the aggregate outcome of "real" sorting costs declining roughly in proportion to volumes may seem relatively benign among USPS's challenges, the aggregates mask significant differences for the letter- and flat-shape mailstreams as well as for component products. Volumes

of flat-shape mail fell markedly faster than letter mail—46 percent versus 31 percent—and upward pressure on unit costs for flat-shape products from sorting operations along with cost coverage issues for some flat-shape mail products has led to increased Commission scrutiny of Postal Service flats costs and operations by the Commission. While concerns regarding flats costs have focused on USPS’s management of flats operations, technological factors may also contribute to the extent the unit-elasticity assumption is incorrect.

This report examines data on automated letter and flat sorting operations covering the PAEA period to date, FY2007-FY2019. We briefly review the primary letter and flat sorting technology used in the PAEA period and the relationship between mail processing volume measures, machine runtime, and associated mail processing workhours. We characterize the paths of total sorting output, average scale of operations, machine throughputs, and labor productivities, for the three main equipment types: DBCS equipment for letters, and AFSM 100 and FSS equipment for flats. We estimate models of runtime and labor demand to investigate the flexibility of machine utilization and workhours over the period.

II. Overview of Letter and Flat Sorting Technology

At the beginning of the PAEA period, the Postal Service’s letter and flat automation programs were still evolving towards their present state. While letter automation technology was relatively mature, OCR and earlier barcode sorting equipment had not been completely retired as of FY2007. Still, the vast bulk of letter sorting was carried out on the Delivery Barcode Sorters (DBCS) that make up the current fleet of letter-sorting equipment. For flats, the processing system was transitioning towards its current state. By FY2007, the current workhorse flat sorter, the AFSM 100, had replaced the earlier FSM 881. In addition, a substantial amount of flat sorting was also carried out on UFSM 1000 machines—now mostly retired—while the Flat Sequencing Sorter (FSS) was in the R&D stage of development.

The lower degree of technical challenge in automating letter sorting versus flat sorting is evident from the comparative operating characteristics of the DBCS and flat sorters. Articles in the letter mailstream tend to be more uniform in dimensions and weight, and physically more capable of high-speed processing.³ Using a single induction station, a DBCS machine can process upwards of 40,000 pieces per hour of machine runtime. The standard DBCS staffing is one clerk feeding mail, which arrives at the machines trayed and uniformly faced, and a second clerk sweeping mail from the output stackers.⁴ DBCS machine speed is relatively constant⁵ and the DBCS’s high

³ Most pieces compatible with letter automation are enveloped or printed on cardstock. Open-sided pieces such as folded self-mailers and ‘slim-jim’ letter-size catalogs are tabbed to improve automation compatibility.

⁴ The descriptions of operations are based on McCrery (2006), which remains applicable for DBCS and AFSM 100 operations. It is possible to operate equipment with more and less staff than the normal requirements, potentially at some cost to throughput and/or productivity.

⁵ DBCS induction speed will slow down if the machine is fed a sequence of pieces near the maximum weight for automation letters; this situation is rare in practice.

feed rate ensures that it will quickly be starved of mail if not continuously fed. DBCS machine runtime in principle should be nearly proportional to pieces fed.

Flats, in contrast, exhibit much wider size and weight variation, and induction speed is limited by the ability of some types of pieces such as catalogs to withstand being accelerated by their cover pages. Thus, to achieve throughput less than half that of a DBCS, AFSM 100 machines employ three induction stations. The standard complement of early AFSM 100 machines in full operation was 5 clerks – three feeders and two sweepers. Tradeoffs between throughput and productivity for the AFSM 100 may be more difficult to manage compared to DBCS. For instance, operating the machine with a full complement (maximizing throughput by utilizing all induction stations) may not maximize productivity if volumes are unexpectedly low.

In addition, while flats prepared in tubs (or which arrive in tubs from upstream operations) could be fed directly into the AFSM 100, similar to the handling of trayed letters on the DBCS, bundled flats cannot be unpackaged, faced, and fed fast enough by induction clerks to keep up with the AFSM 100's induction rate. Thus, the AFSM 100 (and the FSS) requires auxiliary flat preparation operations in which bundled mail is unpackaged, faced, and containerized for induction. This additional work further increases the letter-flat labor cost differential.

Upgrades to the AFSM 100, as well as automated material handling on the FSS, also may have limited the machines' staffing flexibility in service of improving productivity at peak volume levels. For example, much of the AFSM 100 fleet was upgraded with automated induction (AI) systems in FY2006 and FY2007. The AI system's automatic feeders allow one clerk to monitor the three induction stations, but require all flats, not just bundled flats, to be prepped into automation compatible trays (ACTs) that circulate between prep stations and the automatic feeders. Integer constraints on staffing feed and prep stations can limit downward flexibility of labor usage when volumes are low and/or declining.

The FSS is, in some respects, similar to a large-scale AFSM 100 with AI. The FSS system includes the FSS sorter and a separate Stand-Alone Mail Prep (SAMP) machine that partly automates the preparation of trays and rolling containers for induction into the sorter. The FSS sorter also incorporates automated container handling features that may introduce "washing-machine cycle" aspects to FSS runtime, whereby various machine processes (which must be staffed) take similar amounts of time irrespective of at least some variations in the amount of mail being processed.

III. Relationship of MODS Workloads, Machine Runtime, and Workhours

Labor usage in sorting operations is composed of five broad types of activities, with potentially distinct relationships to processing volumes (workloads), which in turn may affect the elasticity of labor usage—and hence cost—with respect to volumes:

- Runtime—operating the running machine: loading the machine, sweeping the output bins or stackers in the course of the run, clearing jams, monitoring the machine operation (for

manual operations, the equivalent is the time spent actually sorting mail into the cases or other receptacles);

- Incidental allied labor⁶—handling of mail other than “direct” sorting activities, and related work, by employees assigned to the sorting operation—e.g., obtaining mail from staging areas, and obtaining and disposing of empty equipment;
- Setup and take-down—setting up the equipment in preparation of running a scheme; clearing processed mail from the machine at the end of the run;
- Waiting for mail and activities other than the above not involving the handling of mail;
- “Overhead” activities such as paid break time and clocking in or out.

IIIa. Runtime

The runtime activity constitutes the majority of workhours within letter and flat sorting operations, and so is the largest activity component for the operations covered here. For an idealized technology with constant throughput and fixed staffing, runtime workhours would be proportional to the number of pieces inducted into the operation for processing—Total Pieces Fed (TPF) in MODS terminology. For automated operations:

$$MachineRuntime = \left(\frac{1}{MachineThroughput} \right) \cdot TPF. \quad (1a)$$

$$RuntimeWorkhours = StaffingIndex \cdot \left(\frac{1}{MachineThroughput} \right) \cdot TPF. \quad (1b)$$

The staffing index is the number of workers assigned to the machine; the throughput is the rate at which the machine processes the mail. Equation (1a) implies that a constant-throughput operation will have a unit elasticity of machine runtime with respect to TPF. Equation (1b) implies that with a constant staffing index, labor hours associated with runtime will have the same elasticity with respect to TPF as machine runtime. In other words, the runtime workhours for a constant-throughput technology with fixed staffing per hour of machine runtime will have a unit-elastic relationship to TPF but may have a non-unit elasticity if throughput and/or staffing rates are non-constant. The conceptual basis for the unit elasticity assumption, therefore, depends critically on the whether the underlying sorting technology features constant throughput and fixed staffing rates.

The technical features of DBCS equipment appear to at least approximate an operation with constant throughput and fixed staffing. However, as discussed above, flat sorters including the AFMS 100 and FSS are variable throughput machines and, depending on the details of machine configurations, may also be operated with variable complements of feeders, sweepers, and prep workers. The staffing index and/or throughput terms in equations (1a) and (1b) may vary positively or negatively with processing workloads. For instance, increasing the staffing index

⁶ “Allied labor” is a term used for mail processing activities that do not directly involve sorting mailpieces, such as transporting mail within facilities, dispatching mail, loading or unloading containers of mail, etc. In this case, the term “incidental” denotes activities that are performed by employees clocked into the MODS operations for sorting operations, rather than MODS operations dedicated to allied labor activities such as platform operations, transporting mail within facilities, opening units, or dispatching.

can, to some extent, increase throughput towards a machine's technical limits at some cost to productivity. If the staffing index and/or machine throughput depend on the TPF volume processed on the equipment, even the runtime portion of labor demand for the machines will not necessarily be unit-elastic.

The workhours associated with operating running machines cannot be separated from the workhours for the other component activities, and the actual staffing levels of the operations are not observable. However, the machine runtime is observed, since it is reported to MODS via the webEOR system. Thus, it is possible to test whether the machine utilization time underlying the runtime activity has a unit elasticity with TPF from equation (1a).

IIIb. Incidental Allied Labor

In addition to the work time spent sorting the mail, a portion of the time in sorting operations is spent on incidental allied labor activities, denoting activities such as moving mail and equipment into and out of the operations carried out by employees clocked into the sorting operation. For AFSM 100 and FSS operations, this category would also include flat preparation work, which is half or more of total workhours for the operations. As with runtime, the amount of labor required for these activities will depend on the amount of mail processed—TPF—though the amount of the work also depends on additional factors such as the containerization profile of the mail and facility layout differences affecting distances (and hence labor time) for moving mail between sorting operations and staging areas.

In a declining-volume environment, universal service requirements place floors on labor needed to serve many destinations. Lower-volume destinations will receive one container per processing cycle, largely independent of volume, and labor productivity for such activities may depend on the density of volume across the network. More generally, the degree of variability of container handling depends on the extent to which changes in volumes cause changes in the number of container handlings on the margin.

IIIc. Setup and Take-Down Activities

Setup and take-down activities may be expected to have little direct relationship to processing volumes on the margin. The essence of setup and take-down activities is that they must be performed once per run of a given sorting scheme, regardless of the quantity of pieces that will run (or have been run) through the scheme.

Setup activities include printing container labels, positioning trays or other containers at the runouts, and loading the sort program. Takedown activities, which tend to be more time-consuming, include removing labels and sweeping all processed mail from each output bin or stacker. The main driver of takedown costs is the number of output separations to be swept, rather than the number of pieces needing to be withdrawn from the machine or the manual operation.

III.d. Waiting and Other Activities Not Handling Mail

Employees in sorting operations spend a small fraction of their time waiting for mail or waiting for machines to be restarted following machine downtime. A portion of waiting time is treated as a zero-elasticity cost in the Commission's mail processing model.

III.e. Overhead Time

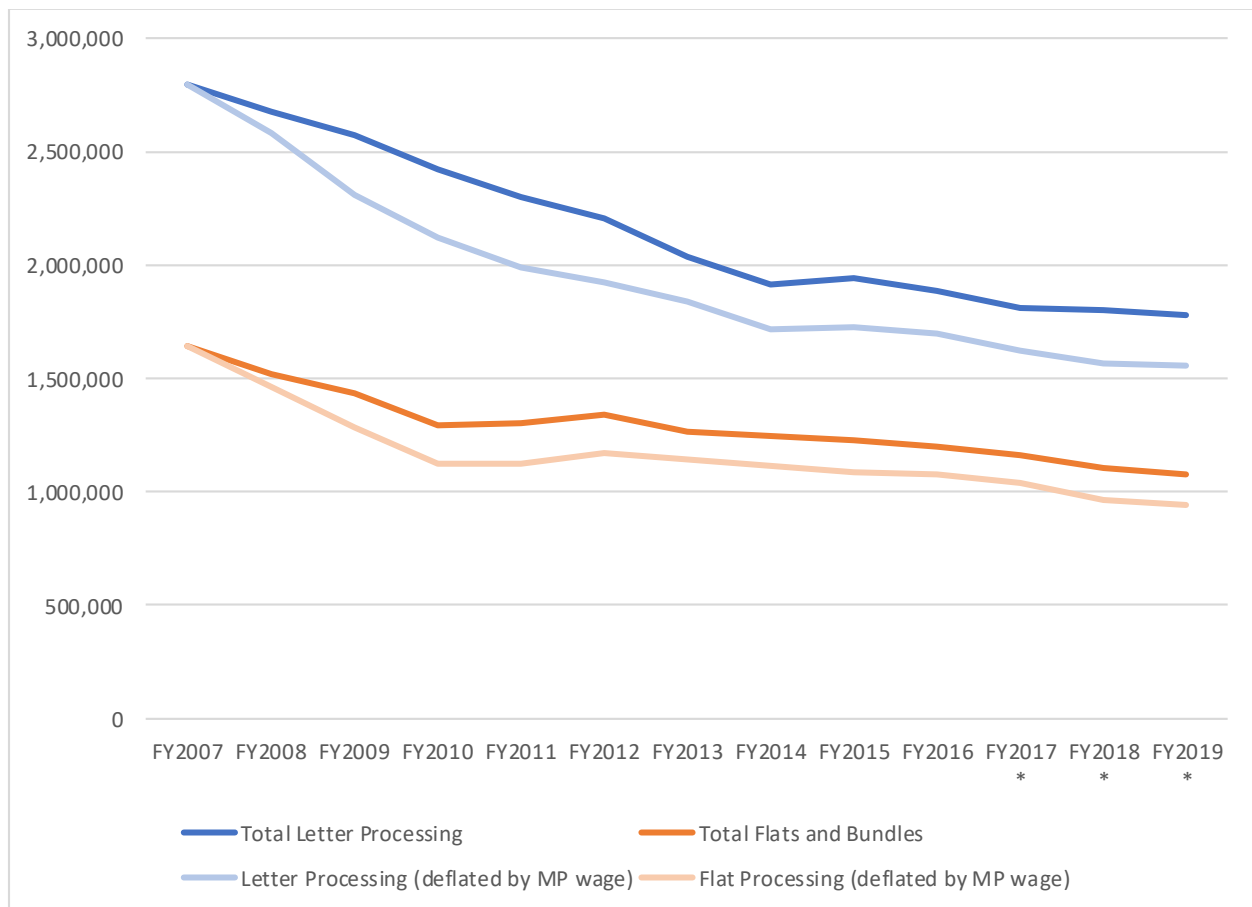
Finally, overhead time—including on-the-clock breaks and “personal needs” time, and time spent clocking into or out of an operation—traditionally was considered to be generated as a byproduct of “productive” work time, and thus were attributable to the same degree as other mail processing costs. As a result, while overhead activities comprise a relatively large fraction (up to 20 percent or so) of sorting operations' labor, they traditionally have been regarded as not affecting the degree of volume-variability. The traditional view of mail processing overheads may reflect some activities better than others. For example, on-the-clock breaks may be earned in rough proportion to other workhours, and hence should have a similar relationship to processing volumes. Others, such as clocking in or out at the beginning and end of shifts may be more similar to set-up and take-down activities in that the time required may not vary on the margin directly with the amount of mail processed on a shift.

Overall, to the extent sorting work does not follow simple constant-throughput, fixed-proportion technology, then elasticity of labor demand for those activities with respect to workload is ambiguous and a matter for econometric estimation to determine.

IV. Trends in Letter and Flat Sorting Costs, Workload, Workhours, and Productivity

Domestic letter and flat mail volume declined 5 percent from FY2007 to FY2008, then plunged 13 percent the following year with the onset of the Great Recession before the rate of decline moderated to lower single digit percentages in FY2010 and subsequently. As shown in Figure 1, sorting labor costs at USPS plants declined overall for both letter and flat operations, both in nominal and real (wage-adjusted) terms. The rates of decline in both cases were somewhat more rapid in the earlier years of the period, particularly for flats, and leveled off somewhat in later years—after FY2014 for letter operations. Cost reductions lagged volume declines somewhat, and notably did not keep up with volume loss from FY2008-FY2009.

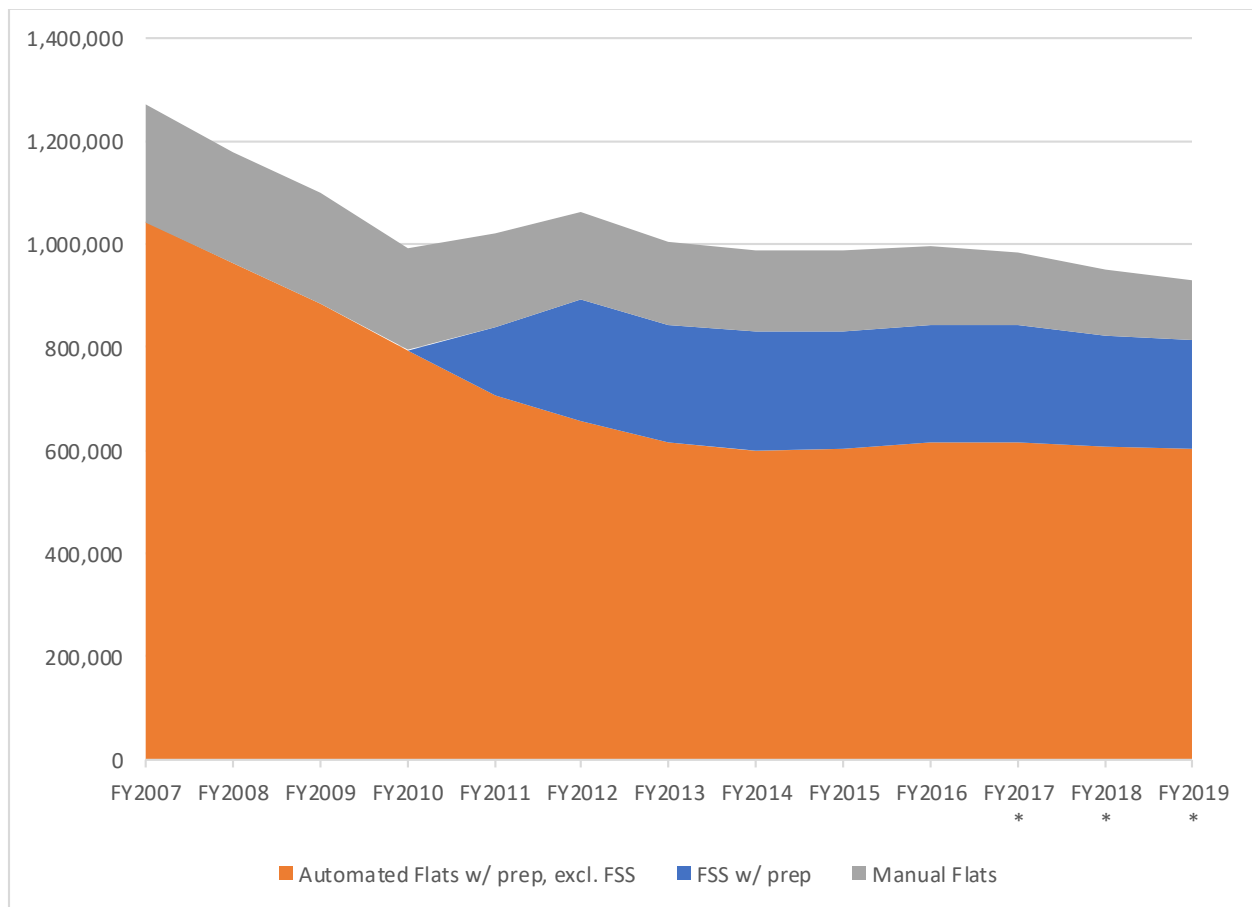
Figure 1. Annual Labor Cost for Letter and Flat Sorting, FY2007-FY2019



Source: USPS-RM2020-13-1, FY07-19 MP Costs w-RPW_v.xlsx, tab 'Fig 1 Plant Sorting Costs by Shape'

A significant change for flat operations was the FSS deployment, which accounts for the leveling off of flats costs between FY2010 and FY2012. FSS processing substitutes in part for incoming secondary sorting in AFSM 100 operations, for some flat sorting at destination post offices, and for some carrier casing of flats. The latter two factors would be expected to increase measured mail processing costs at plants (other things equal). As shown in Figure 2, which shows the composition of costs within flats operations, the temporary increase in flat sorting costs at plants is associated with the wider deployment of FSS equipment and the corresponding increase in FSS costs, offsetting declining costs for AFSM 100 and other operations.

Figure 2. Composition of Plant Flat Sorting Costs, FY2007-FY2019



Source: USPS-RM2020-13-1, FY07-19 MP Costs w-RPW_v.xlsx, tab 'Fig 2 Flats Cost Composition'

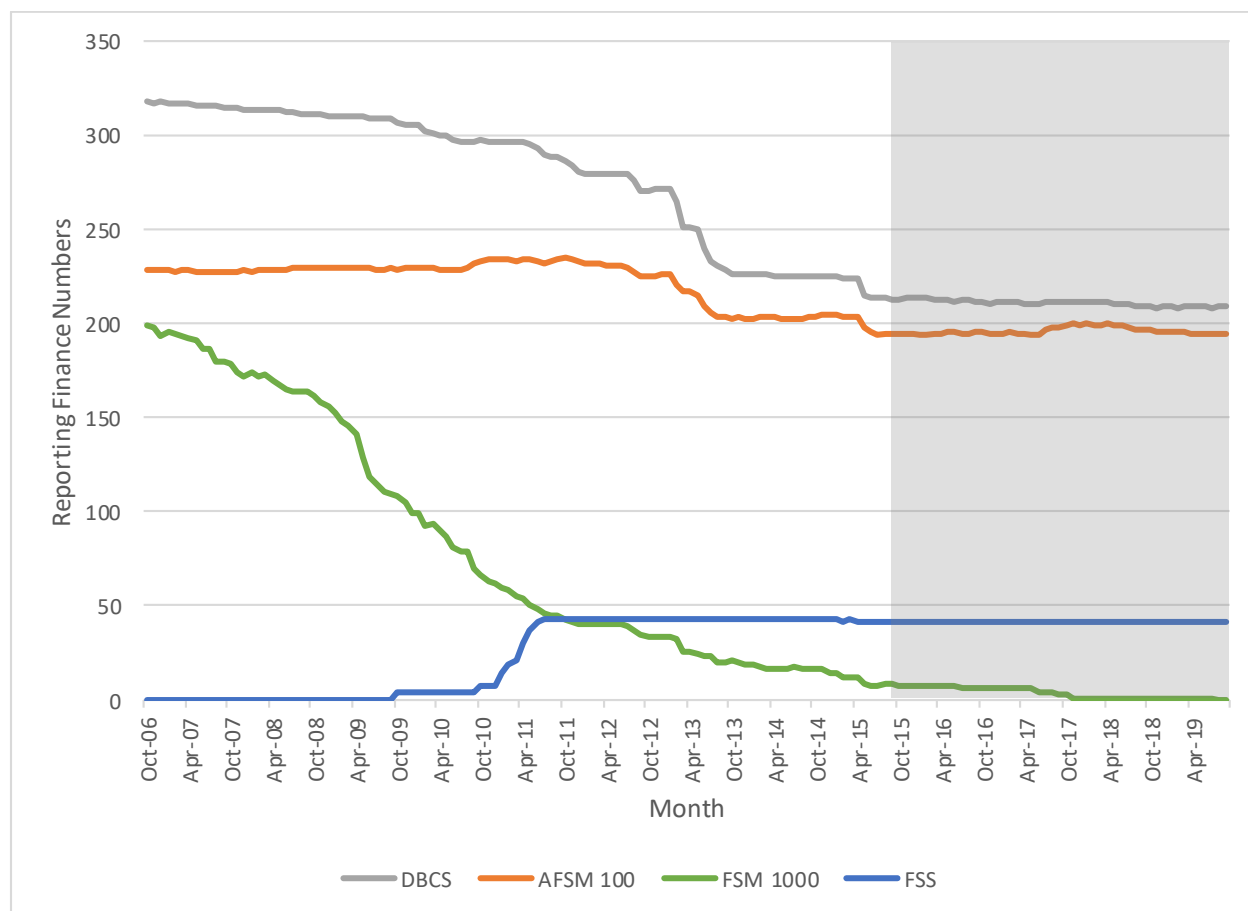
Among USPS's efforts to adjust operations to reduced volumes were closings and consolidations of mail processing facilities. Figure 3 shows the number of facilities (finance numbers) reporting activity in the main automated letter and flat processing operations in MODS. Automated letter sorting (DBCS cost pool) operations are the most widely implemented automated processing operation in the USPS mail processing system. The number of facilities with active DBCS operations declined slightly in the early PAEA period, and more significantly from FY2011-FY2013.

In contrast, the number of facilities with AFSM 100 operations actually increased slightly, likely representing reallocation of machines to facilities that previously lacked automated flat sorting equipment. Older UFSM 1000 flat sorters were rapidly being retired from FY2007-FY2011, and nominal FY2015 costs in the FSM 1000 cost pool were 2 percent of FY2007 costs.⁷ FSS

⁷ The primary purpose of the UFSM 1000 was to sort flats with size and/or rigidity characteristics that would render them non-machinable on other flat sorting equipment, though it was also able to process machinable flats. In the FY2016-2019 period, UFSM 1000 operations were analytically negligible.

equipment was deployed mainly in FY2010-FY2011. From FY2016, the shaded area, the numbers of processing facilities reporting the main letter and flat operations has been relatively stable in the absence of further processing network consolidation or deployments of new letter and flat sorting equipment.

Figure 3. Number of Facilities Reporting Activity in Selected USPS Processing Operations, FY2007-FY2019



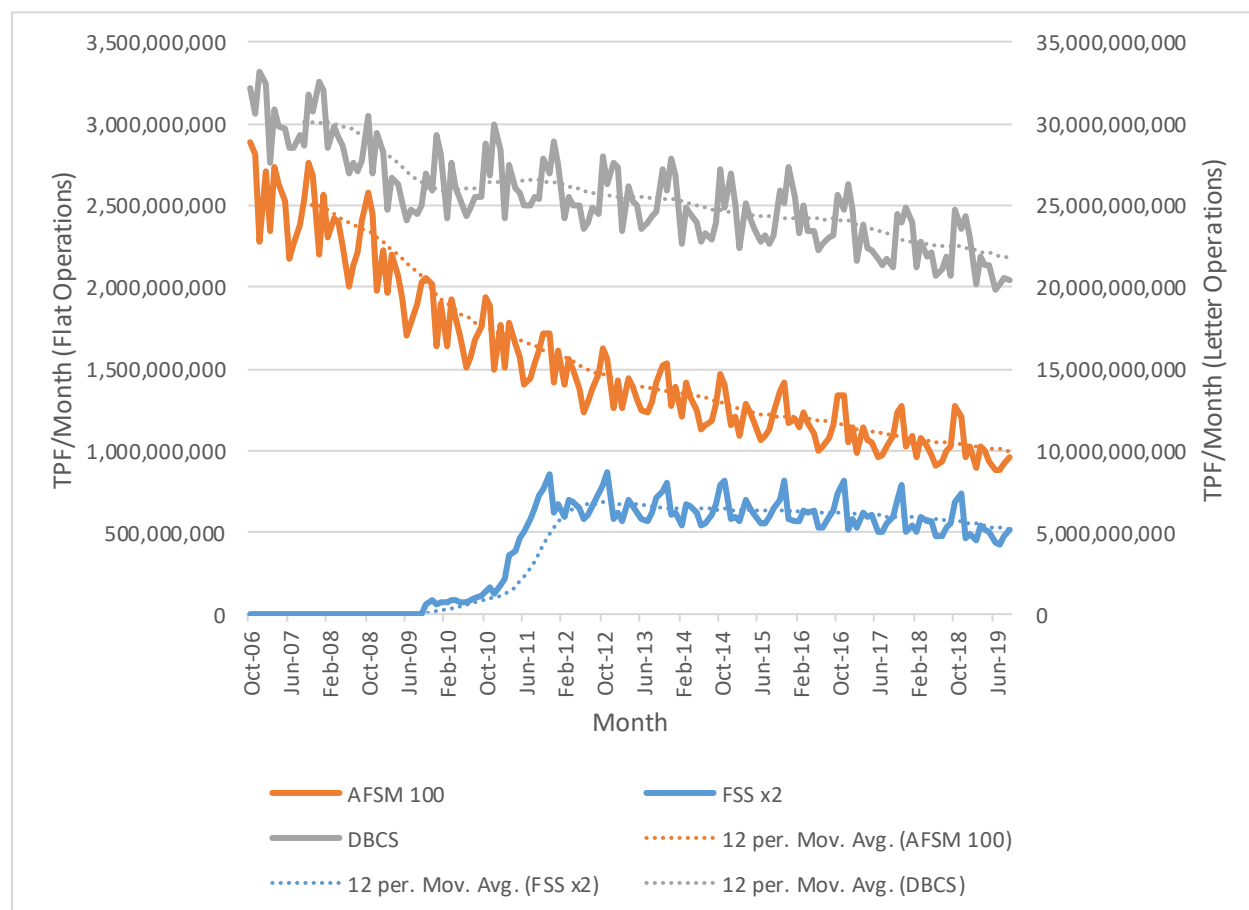
Source: MODS; USPS-RM2020-13-1, Figure 3 Facilities.xlsx.

Figure 4 shows monthly workloads for automated letter and flat processing, measured by Total Pieces Fed (TPF). As noted above, TPF is a direct machine count of the articles inducted by the machine for automated sorting operations, including both successfully sorted items as well as machine rejects, and is the primary driver of machine runtime as well as a driver of other labor requirements.

Letter and flat TPF show considerable within-year variation, reflecting seasonal mailing peaks. To show the trends, the figure includes 12-month moving averages of TPF. Both letters and flats exhibit overall mailing peaks late in the calendar year, though flats workload peaks in October-November whereas letter workload typically peaks in December.

Delivery point sequencing on both the DBCS and FSS uses a two-pass sorting process. On the DBCS, the two sort passes for a successfully sorted piece result in two TPF counts, whereas the FSS records a single TPF representing both sorts. While AFSM 100 equipment is not used for delivery point sequencing, it also measures one TPF per sorting pass. Thus, FSS TPF are multiplied by 2 to put the TPF measurements on equal footing with the DBCS and AFSM 100 TPF measures.

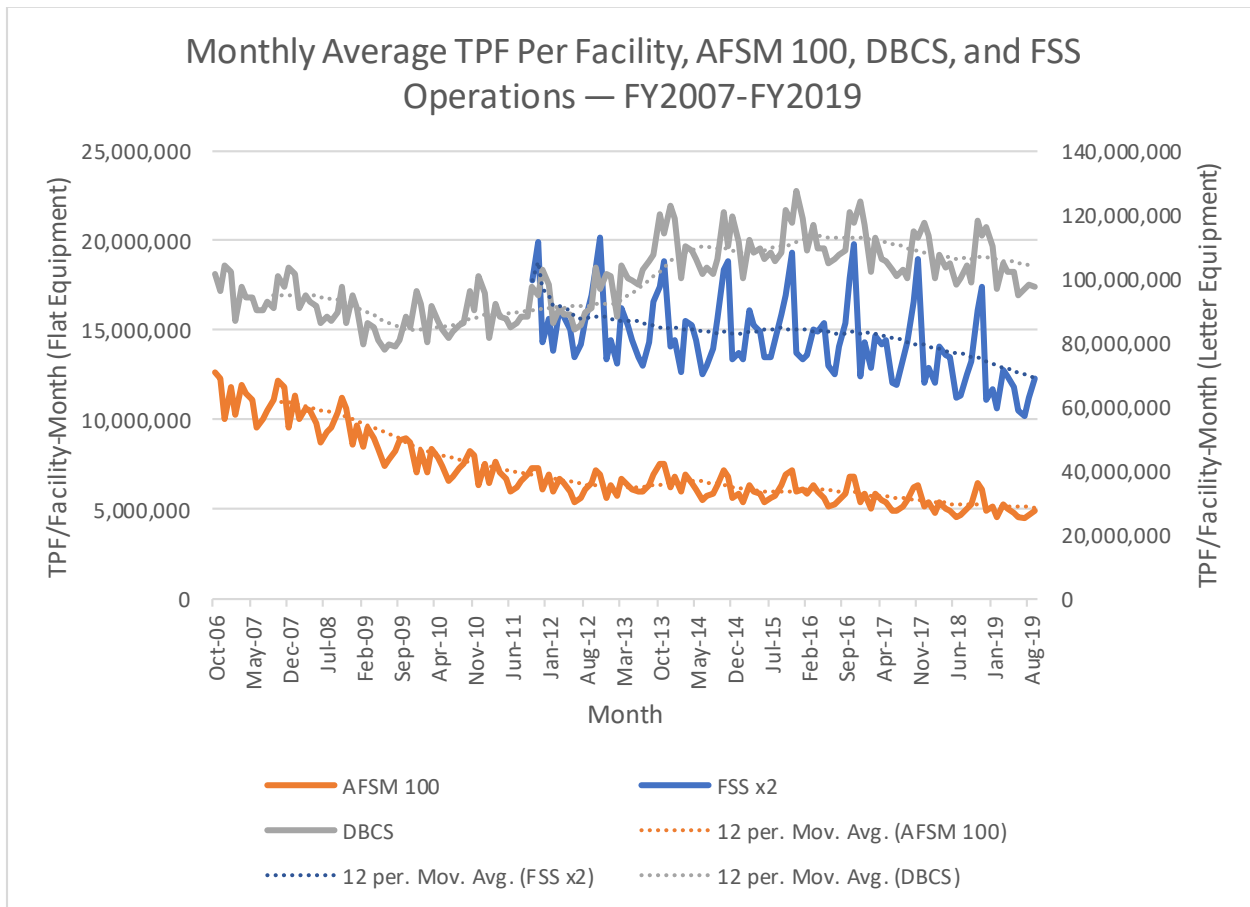
Figure 4. Monthly TPF, AFSM 100, DBCS, and FSS — FY2007-FY2019



Source: MODS; USPS-RM2020-13-1, Figure 4 TPF.xlsx.

While the overall output of letter and flat processing operations broadly declined along with volumes, facility consolidation would have moderated the effect of the volume decline on the average scale of the remaining operations. Figure 5 shows the average TPF workloads per facility. Indeed, facility consolidations were such that the average scale of DBCS letter-sorting operations increased for several years following an initial decline during the recession. Flat operations, in contrast, were subject to less consolidation and saw generally declining average scale over the same time. All three operations have more recently exhibited declining average scale in the absence of significant facility consolidation since FY2015.

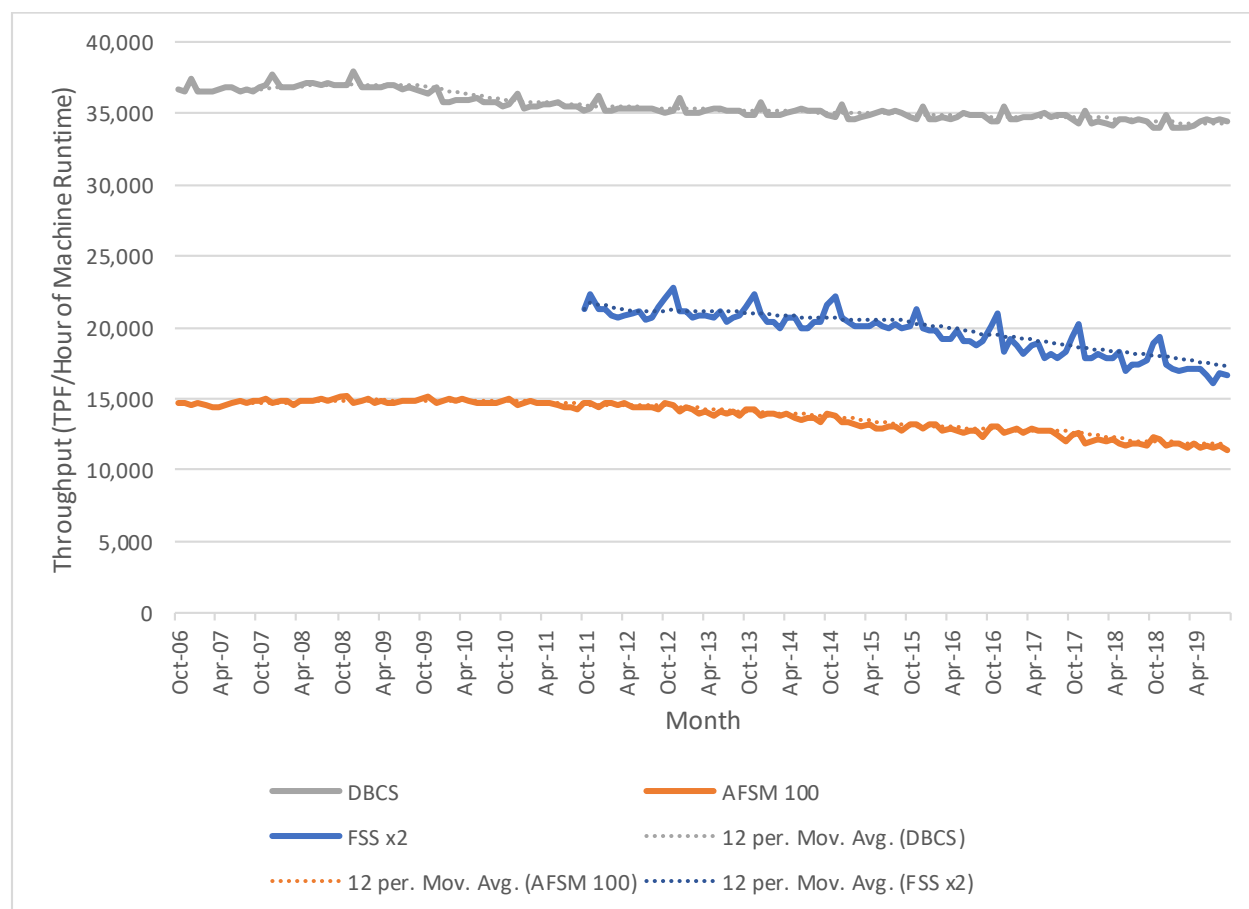
Figure 5. Monthly Average TPF Per Facility, AFSM 100, DBCS, and FSS — FY2007-FY2019



Source: MODS; USPS-RM2020-13-1, Figure 5 Scale.xlsx.

Throughput is the quantity of TPF processed per hour of machine runtime. TPF and runtime are both also machine operating statistics automatically transferred to the MODS system via the webEOR (End-of-Run) system. While workloads show considerable seasonal variability, letter and flat automation throughputs show relatively limited seasonal variation, as shown in Figure 6. DBCS operations show a slight seasonal throughput peak in December. FSS throughput also shows peaks coincident with the November flat workload peak, though there is little sign of a matching throughput peak for AFSM 100 operations. The throughput data indicate that current-period workload and runtime vary together relatively closely within years.

Figure 6. Machine Throughput (TPF/Runtime), AFSM 100, DBCS, and FSS Operations — FY2007-FY2019



Source: MODS; USPS-RM2020-13-1, file “Fig 6 Throughput.xlsx.”

The primary measure of labor productivity for USPS automated sorting operations is TPF per workhour.⁸ In contrast to TPF and runtime, which are machine statistics, workhours are derived from time clock rings reported to MODS through the Time and Attendance Collection System (TACS), the USPS electronic timekeeping system. The accuracy of workhours thus depends on the extent to which employees are clocked into operation codes corresponding to their actual work activities. The accuracy of workhours thus tends to be more variable than processing equipment’s operating statistics, though at relatively high levels of aggregation (such as total workhours for major equipment types), USPS believes the data to be relatively accurate.

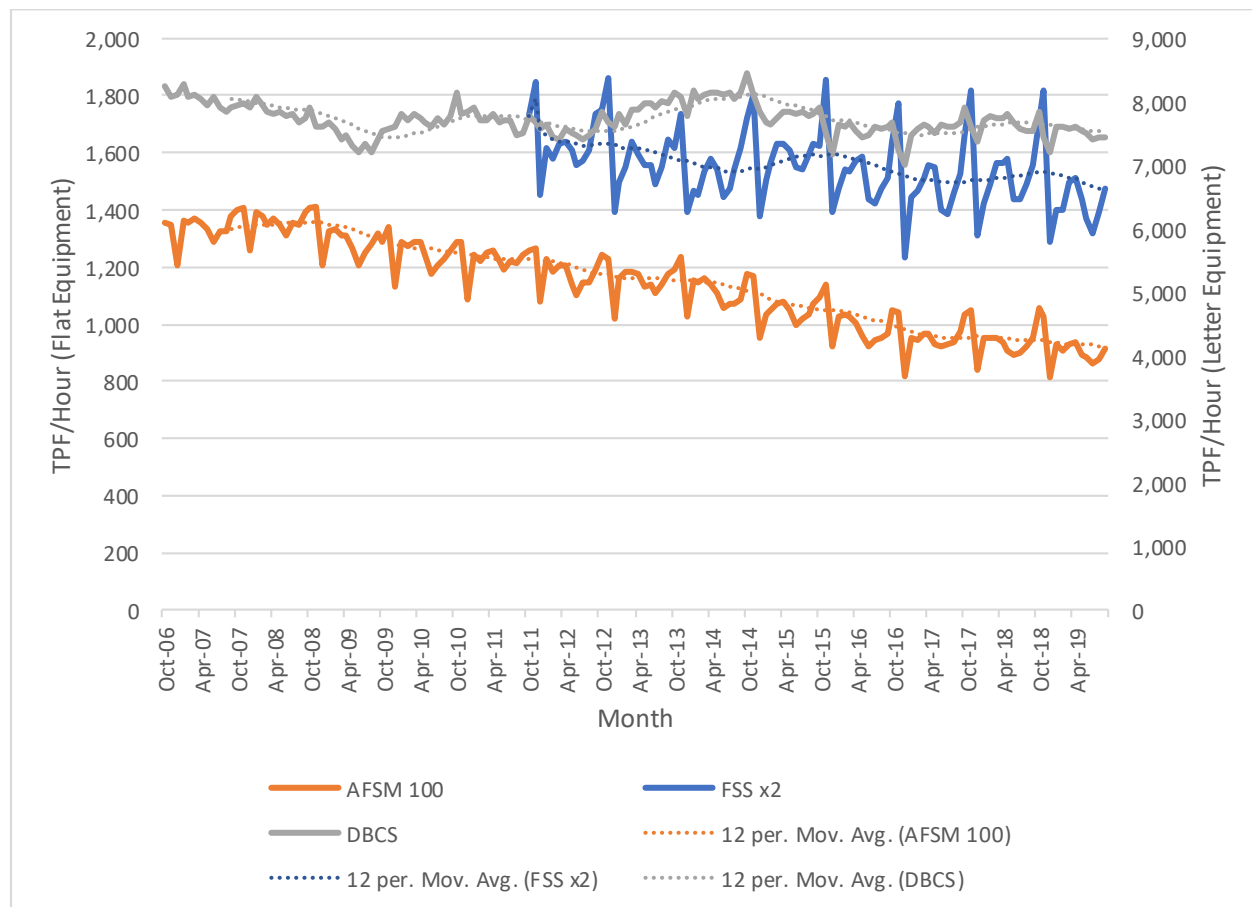
Labor productivity data are shown in Figure 7. The productivity data shows more variability within the year than throughput, particularly for flats operations, which may be expected from seasonal variability in workload and short-term inflexibilities in USPS labor utilization. The

⁸ See, e.g., Docket No. ACR2019, USPS-FY19-23. The labor productivities reported in USPS-FY19-23 are used to populate a number of engineering-economic models of mail flows used to estimate cost differences for rate categories within products.

productivity data have several interesting features. First, while DBCS productivity declined initially—reaching a low point in late FY2009, when volume, workload, and scale all were declining—productivity subsequently stabilized and increased during the period when facility consolidations drove an increase in average scale. With generally declining scale, AFSM 100 productivity exhibits a more consistent downward trend. FSS productivity has also exhibited downward trends in productivity and average scale, though with a less consistent rate of decline.

Second, the seasonal workload peaks for letters and flats appear to have opposite-direction effects on letter and flat productivities. While a seasonal pattern for DBCS is not entirely consistent, from FY2013-FY2019 the December productivity was below the moving-average trend, where throughput shows a small above-trend peak. This suggests that for the seasonal letter peak, additional DBCS labor increases throughput somewhat at a cost in productivity. In contrast, both AFSM 100 and FSS operations consistently show substantially above-trend productivity during the October-November peak period, and correspondingly below-trend productivity in December, when flat workload shows a strong seasonal decline. The productivity data suggest that either USPS flat operations largely absorb seasonal peaks in volumes, operate at more efficient scales in peak periods, or perhaps a combination of the two.

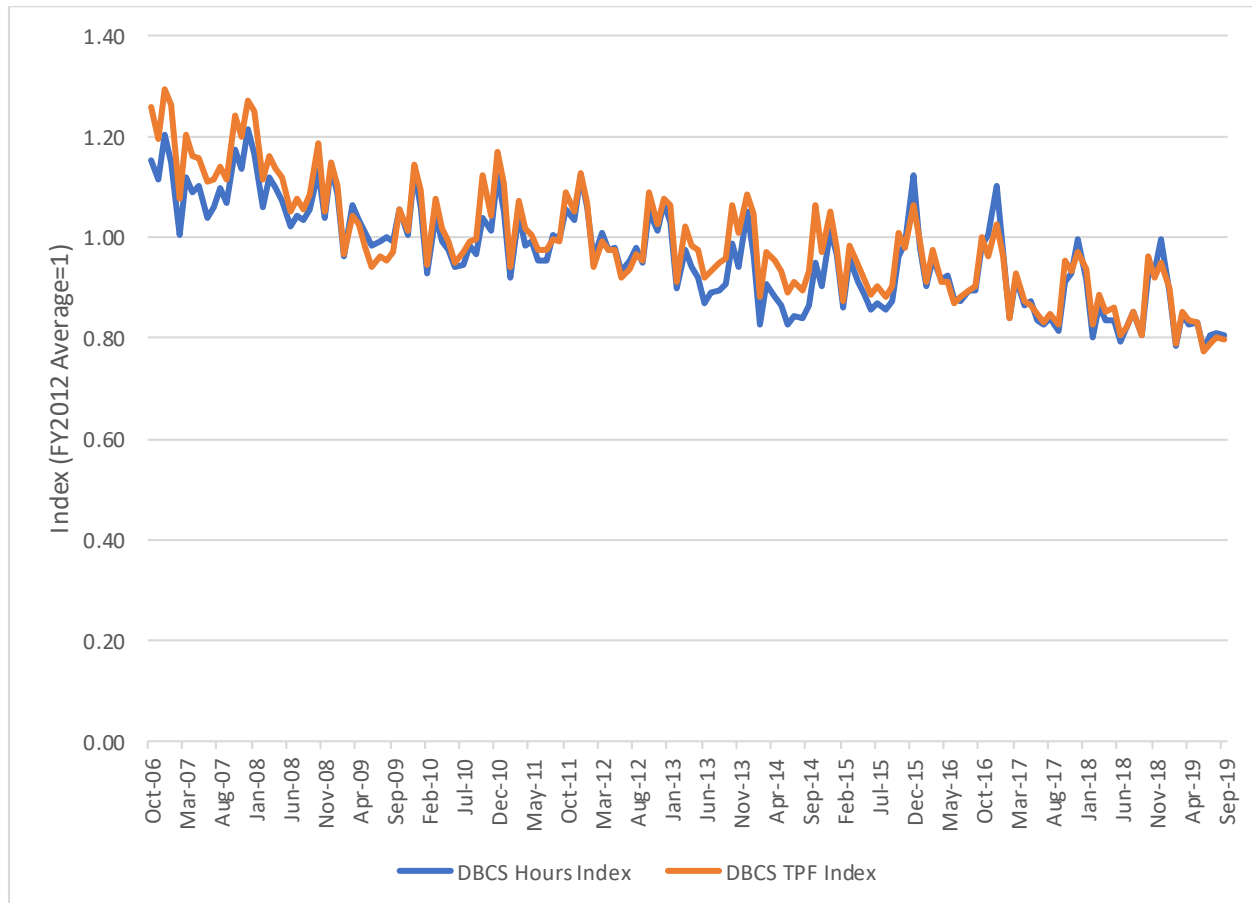
Figure 7. Automated Letter and Flat Productivity (TPF/Workhour), Monthly, FY2007-FY2019



Source: MODS; USPS-RM2020-13-1, file “Fig 7 Productivity.xlsx.”

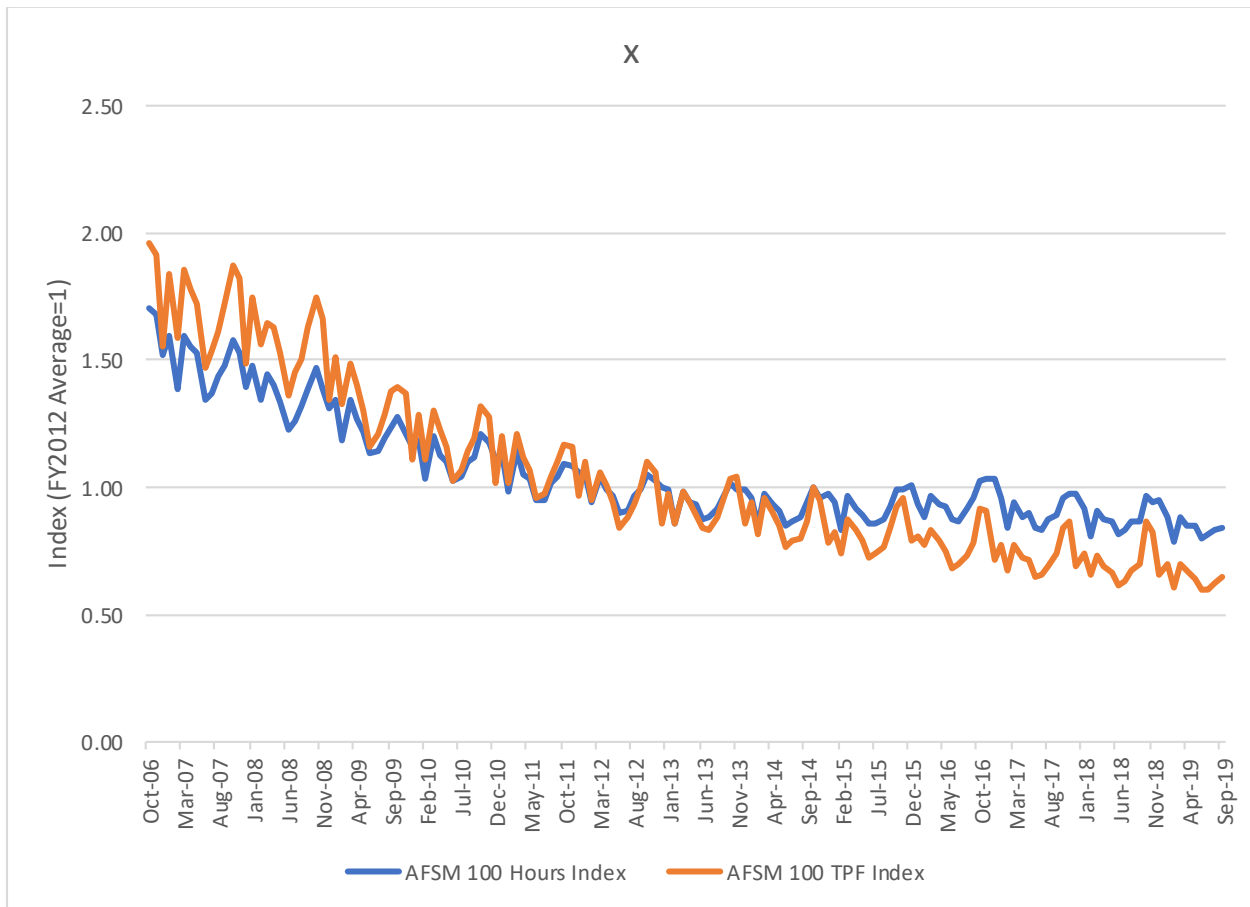
Figures 8-10 show indexes of monthly TPF and workhours for the three equipment types, with the indexes based to the FY2012 averages for each variable. These figures show that TPF and workhours largely move together both at monthly frequency within years and over longer periods of time, though longer-term divergence of the trends suggest that the co-movements are not necessarily reflective of unit or near-unit labor elasticities with respect to TPF (output). The deviations in the workhour and TPF trends are more pronounced for the AFSM100 and FSS flat operations than DBCS operations.

Figure 8. Index of Monthly TPF and Workhours - DBCS — FY2007-FY2019



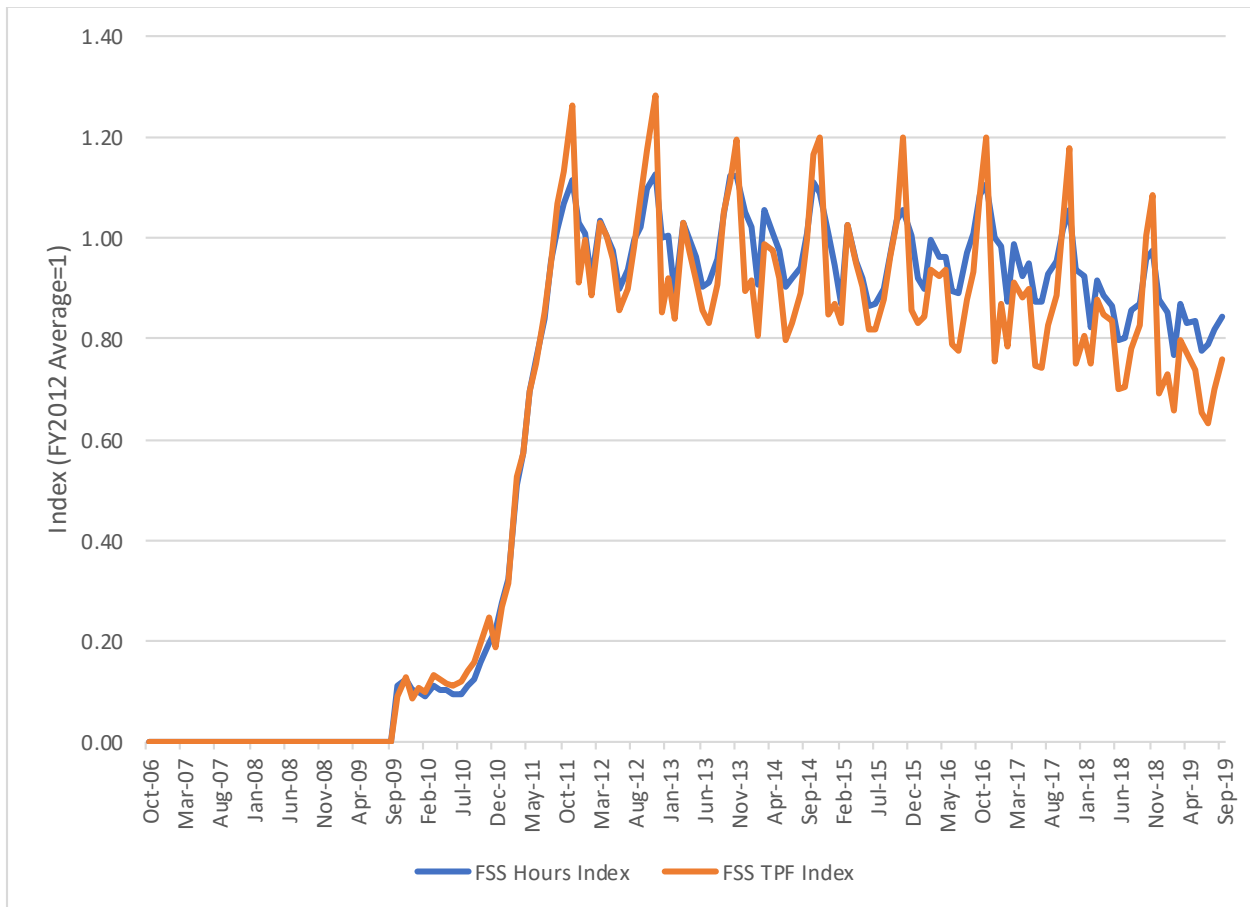
Source: MODS; USPS-RM2020-13-1, file “Figs 8-10 TPF-Hours.xlsx.”

Figure 9. Index of Monthly TPF and Workhours – AFSM 100 — FY2007-FY2019



Source: MODS; USPS-RM2020-13-1, file “Figs 8-10 TPF-Hours.xlsx.”

Figure 10. Index of Monthly TPF and Workhours - FSS — FY2007-FY2019



Source: MODS; USPS-RM2020-13-1, file “Figs 8-10 TPF-Hours.xlsx.”

V. Variability of Machine Runtime and Labor Input for Letter and Flat Sorting Equipment

As discussed above, the elasticity of machine runtime and labor usage depends on the volume of mail processed (MODS TPF), but the elasticities with respect to TPF are indeterminate. We estimate log-linear models for machine runtime and workhours using monthly data by plant:

$$\ln MachineRuntime_{it} = a_i + b \ln TPF_{it} + e_{it} \quad (2)$$

$$\ln Workhours_{it} = a_i + b \ln TPF_{it} + e_{it} \quad (3)$$

In the log-linear specifications of equations (2-3), the coefficients b on $\ln TPF$ have a direct interpretation as the elasticities of runtime or workhours with respect to TPF output. Unit elasticity with respect to TPF, then, is a special case corresponding to the restriction $b=1$. Given equations (1a-1b) and the discussion in section IIIa, above, the intercepts a_i potentially depend on volume-independent technological parameters, management considerations affecting staffing levels locally, and specific plants' processing network roles. Since these may differ systematically across facilities, the model allows for facility-specific intercepts. Failing to account for unobserved non-volume heterogeneity among facilities generally would lead to biased and inconsistent elasticity coefficient estimates.⁹

We also estimated extended models that allow for a lagged effect of TPF on runtime and workhours, as well as seasonal non-volume effects. While there is relatively little reason to expect that machine runtime should materially depend on workloads other than current-period TPF, workhours may have a longer adjustment process due to limitations on the flexibility of USPS labor. The inclusion of lagged TPF terms allows for adjustment processes of workhours with respect to workloads over longer time scales. Notably, same period last year (SPLY) reporting is a common piece of management information provided by various USPS data systems, including MODS, for managing workhours. Staffing may also be subject to shorter-term constraints. The extended models include the first and twelfth lags of monthly TPF, the latter being the same month in the previous year.

Figures 8-10, above, suggest that while workhours and TPF generally move together from month to month within years, there may nevertheless be some residual seasonal (monthly) variability in workhours that is not explained by corresponding variations in TPF. Allowing for purely seasonal effects via monthly dummy variables helps ensure that purely seasonal effects on workhours are not inappropriately captured in the estimated elasticities.

The estimating equations for the extended models are:

⁹ See, e.g., Cheng Hsiao (1986) for a treatment of estimation with unobserved latent variables. The fixed-effects model is consistent when the latent variables are correlated with the observed variables, which is the general case. Other estimators, such as the random-effects model, may be efficient in the special case of unobserved effects that are uncorrelated with the other regressors (in which case, the fixed-effects model remains statistically consistent), but inconsistent if the zero-correlation requirement is violated.

$$\ln MachineRuntime_{it} = a_i + b_1 \ln TPF_{it} + b_2 \ln TPF_{i,t-1} + b_3 \ln TPF_{i,t-12} + c \cdot D_{m(t)} + e_{it} \quad (4)$$

$$\ln Workhours_{it} = a_i + b_1 \ln TPF_{it} + b_2 \ln TPF_{i,t-1} + b_3 \ln TPF_{i,t-12} + c \cdot D_{m(t)} + e_{it} \quad (5)$$

In equations (4) and (5), the term $c \cdot D_{m(t)}$ represents a linear combination of dummy variables indicating the month associated with period t . For the extended models with lags, we take the TPF elasticity to be the sum of the coefficients b_1 , b_2 , and b_3 .

Choosing a sample period for the analysis requires balancing several competing factors. The sample period should be long enough to allow the model parameters—including lagged terms and facility-specific intercepts—to be identified and estimated, but not so long that the results may not be representative of the current operating environment. From Figure 3, it may be seen that using the full FY2007-FY2019 period following the enactment of PAEA would encompass multiple operating environments for flats, since the earlier years in the period had significant UFSM 1000 operations and predated FSS. For both letter and flat operations, earlier years of the PAEA period include periods of facility consolidation and related network changes, extending through FY2015. The FY2016-FY2019 period features a relatively fixed operating environment including technology mix, while providing sufficient regression sample sizes, and serves as the sample period for the main estimation results.

We found that the estimated elasticities for workhours were somewhat sensitive to the inclusion of outliers with unusual values for labor productivity in regressions using unscreened data. As automatically generated machine operating statistics, the estimated elasticities for runtime were relatively insensitive to data screening. We report results for both dependent variables after screening so that the results are for comparable sets of observations.

While productivities vary across plants for a number of reasons, extreme values may reflect idiosyncratic errors or other factors not fully captured by the model. Accordingly, the regression samples exclude observations where the measured labor productivity is below the 5th percentile or above the 95th percentile of the distributions of site-month observations. Table 1 shows the productivity cutoff values for the screen at the 5 percent tails. The resulting productivity ranges for the regression samples are operationally plausible.

Table 1. Productivity Cutoffs for 5% Tail Screens

Operation	Lower 5% Cutoff	Median	Upper 5% Cutoff
AFSM 100	733	1,225	1,855
DBCS	6,299	8,314	11,219
FSS	548	787	1,184

Summary statistics for the screened and unscreened FY2016-FY2019 data are shown in Table 2. The screened means of workload (TPF), workhours, and runtime are within 5 percent of the

unscreened values, indicating that the screening does not lead to large differences in the sample composition versus the population.

Table 2. Summary Statistics for Regression Variables, FY2016-FY2019, Screened and Unscreened

Operation	Screened	Hours	TPF	Runtime	Throughput	Productivity
AFSM 100	N	5,729	5,480,766	443	12,547	1,127
AFSM 100	Y	5,465	5,577,906	447	12,707	1,108
DBCS	N	14,344	108,487,888	3,136	34,993	9,022
DBCS	Y	14,004	108,649,371	3,136	35,054	8,303
FSS	N	9,091	6,880,563	744	9,311	814
FSS	Y	9,343	7,134,553	772	9,343	779

Results for the runtime equations (2) and (4) for the FY2016-FY2019 sample period are shown in Table 3. The corresponding results for the workhour equations (3) and (5) are shown in Table 4.

The full-sample results show that DBCS runtime has a near-unit elasticity with respect to TPF in both estimating equations. While the estimated elasticities have statistically significant differences from 1 given the small standard errors of the estimates, the difference is less analytically significant. DBCS letter sorting appears to behave much like a constant-throughput technology as a practical matter. The high within R-squared indicates that current-period TPF successfully explains most of the within-site variation in runtime.

Table 3. Regression Results for Runtime Models, FY2016-FY2019 Sample Period

Operation	Elasticity Current TPF (Eq. 2)	Elasticity Current + Lagged TPF (Eq. 4)	F-test H0: Eq. 2	R-Squared (Within)	N
DBCS	0.987 (0.004)	n/a	n/a	0.9684	9,072
DBCS	n/a	0.958 (0.012)	169.93*	0.9719	9,062
AFSM100	0.831 (0.026)	n/a	n/a	0.7876	8,059
AFSM100	n/a	0.771 (0.064)	69.52*	0.7812	7,973
FSS	0.682 (0.029)	n/a	n/a	0.8018	1,792
FSS	n/a	0.600 (0.106)	58.32*	0.8357	1,763

Heteroskedasticity-consistent standard errors in parentheses for elasticities (clustered by panel variable). Asterisk indicates p-value < 0.01.

Table 4. Full-Sample Regression Results for Workhour Models, FY2016-FY2019 Sample Period

Operation	Elasticity Current TPF (Eq. 3)	Elasticity Current + Lagged TPF (Eq. 5)	F-test H0: Eq. 3	R-Squared (Within)	N
DBCS	0.933 (0.015)	n/a	n/a	0.7045	9,072
DBCS	n/a	0.976 (0.032)	35.52*	0.7076	9,062
AFSM100	0.749 (0.079)	n/a	n/a	0.6026	8,059
AFSM100	n/a	0.774 (0.091)	52.23*	0.5940	7,973
FSS	0.593 (0.030)	n/a	n/a	0.5440	1,792
FSS	n/a	0.804 (0.070)	51.43*	0.6025	1,763

Heteroskedasticity-consistent standard errors in parentheses for elasticities (clustered by panel variable). Asterisk indicates p-value < 0.01.

For AFSM 100, the runtime elasticities are somewhat lower, in the vicinity of 0.8. The differences in results by model specification—0.83 in equation (2) without lags and seasonal controls, 0.77 in equation (4) with the additional variables—are not statistically significant. The implication is that variable throughput and automated material handling on upgraded AFSM 100 machines leads AFSM 100 to be a technology where high-output (TPF) periods lead to higher throughput, unlike a constant-throughput technology. This will in turn tend to result in less-than-proportional responses of runtime staffing with respect to output.

For FSS, runtime elasticities are the lowest of the three machine types. The runtime elasticity is lower in the model with lags than without—0.60 and 0.68, respectively—though as with AFSM 100, the differences are not statistically significant. The results are consistent with the more extensive automated material handling systems on the FSS versus AFSM 100, such that cycle times in various stages of processing may be less sensitive to the sorting volumes on the machines.

The workhour elasticities also show a qualitative difference between DBCS letter operations and both AFSM 100 and FSS flat operations. DBCS labor hour elasticities are closer to 1 than the AFSM 100 and FSS estimates, though the difference is statistically insignificant in the equation (5) specification including lagged TPF and monthly dummy variables. For AFSM 100 and FSS operations, the labor elasticities are lower than 1 at statistical confidence levels exceeding 95 percent using heteroskedasticity-consistent standard errors. In models including lags and monthly dummy variables, the estimated elasticities are slightly higher for DBCS and AFSM 100, and much higher for FSS. FSS tends to have relatively extreme seasonal peaks and troughs in productivity, some of which appears to be the result of seasonal non-volume factors rather than a matter of volume response at a low elasticity. Test statistics for the joint inclusion of the lagged TPF and monthly dummy variables strongly reject the null hypothesis that lagged and

seasonal effects are jointly zero, so the estimates from equation (5) are preferred to the results from the simple log-linear models given by equation (3).¹⁰ For the most part, the gaps between runtime and workhour elasticities are larger for flat sorting operations. To the extent activities other than staffing machine runtime have higher or lower elasticities than the runtime portions of the operations, the gap may be driven by the greater prevalence of flat preparation among other types of incidental allied labor in the AFSM 100 and FSS activity mix.

To investigate the stability of the elasticities within the overall FY2007-FY2019 period, we also ran rolling regression analyses using the log-linear models (without lags) in equations (3) and (5). We estimated runtime and workhour elasticities for the three equipment types using rolling 48-month sample windows, with the last window corresponding to the FY2016-FY2019 sample periods reported in Tables 1 and 2. We also examine rolling 60-month windows to investigate the effects of extending the sample period. Earlier sample windows for DBCS and AFSM 100 will cover the June 2009 recession trough (per NBER recession dating), and the recession and facility consolidation periods gradually rolls out of the sample. For FSS, initial results tend to be relatively unstable before the deployment period begins to roll out (including lags, this is in calendar year 2016 for the 48-month samples). Figures 11 and 12 show the runtime and labor elasticities, respectively, from the rolling samples.

We observe that for DBCS, the runtime elasticities increase towards 1 as the recession period rolls out of the samples, which occurs later in the 60-month rolling samples. For AFSM 100 and FSS, the runtime elasticities are lower and generally declining as the sample windows shift forward. The 48- and 60-month samples follow similar paths overall.

¹⁰ For AFSM 100, the joint test that the lagged TPF coefficients are zero does not reject the null hypothesis at standard significance levels (p-value 0.13).

Figure 11. AFSM, DBCS, and FSS Elasticities of Runtime w/r/t TPF (Equation 3 model), Rolling 48-month & 60-month samples

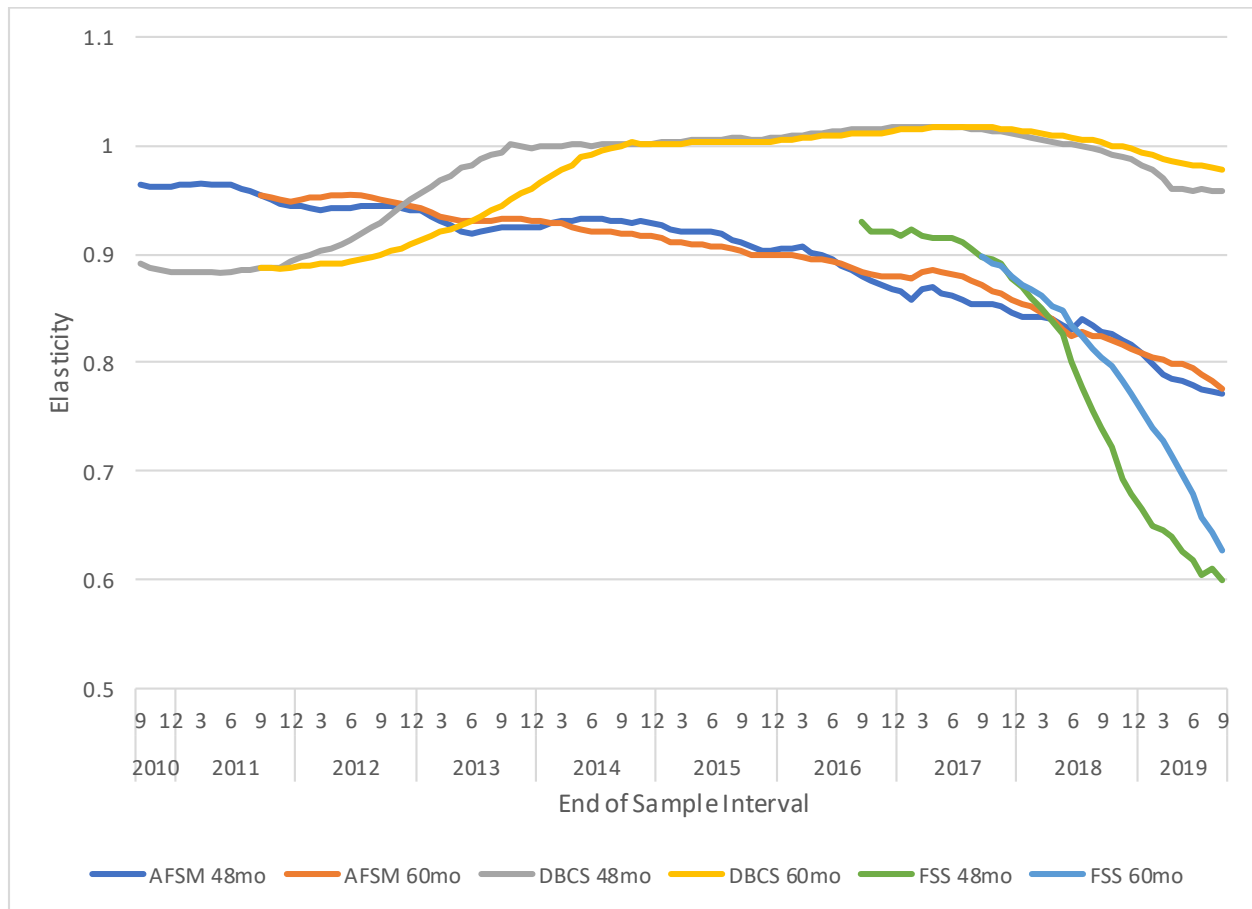
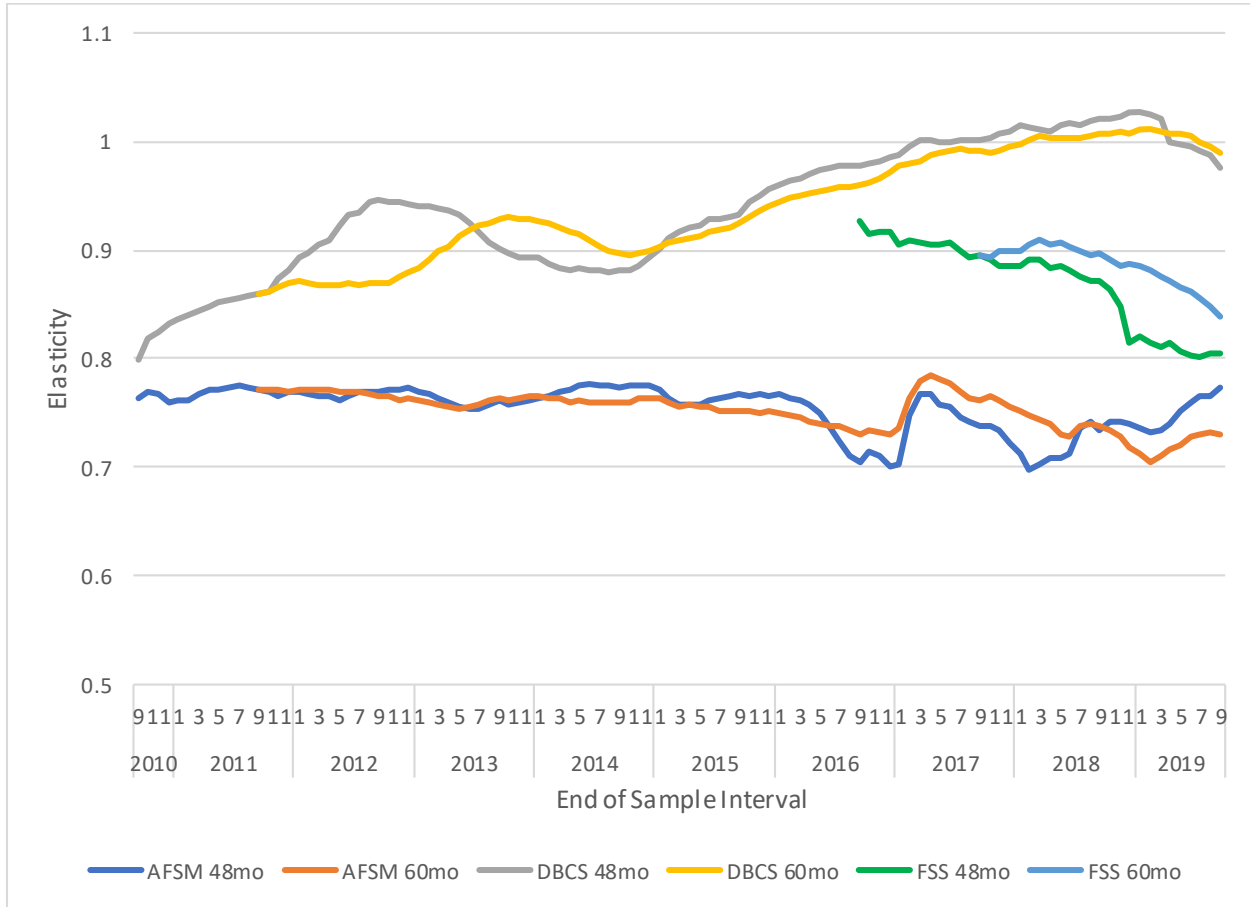


Figure 12. AFSM, DBCS, and FSS Elasticities of Workhours w/r/t TPF (Equation 5 model), Rolling 48-month & 60-month samples



The DBCS and AFSM 100 labor elasticities also follow generally similar paths for 48- and 60-month rolling samples, though some apparent turning points in the series happen later with the longer sample windows. As the recession and facility consolidation periods roll out of the samples, DBCS labor elasticities gradually increase towards values close to the estimates for the FY2016-2019 sample period. The AFSM 100 elasticities show relatively little trend over time, though both the 48- and 60-month samples show some instability in later periods. Nevertheless, the range of elasticities—approximately 0.7-0.78—is relatively narrow and well below 1. While the available trend data are more limited for FSS, the estimated elasticities decline from values around 0.9, partly reflecting a corresponding decline in the series of runtime elasticities.

VI. Conclusion

This paper analyzed the response of machine runtime and labor usage for USPS automated letter and flat sorting in the declining-volume era of the PAEA. The analysis shows notable qualitative differences among DBCS letter equipment and AFSM 100 and FSS flat sorters. Perhaps counterintuitively, the average scale of letter operations increased over much the PAEA period,

due to facility consolidation and other operational changes to direct compatible letter mail to automated processing. In contrast, flat operations consolidated less, in part because flat automation was less broadly deployed at the end of the PRA era, and faced larger volume and workload declines combined with less opportunity for operation consolidation. Thus, the average scale of flat sorting operations broadly declined.

The changes in average scale would be irrelevant to changes in costs and productivities if the operations' resource usage was unit elastic with respect to workload. Indeed, the analysis of runtime data shows that the DBCS relatively closely approximates a constant-throughput technology, and while both its runtime and labor demand elasticities with respect to counts of processed pieces (TPF) have point estimates below 1, the economic significance of the difference from PRC costing assumptions is relatively minor. Automated flat sorting, in contrast, does not use constant-throughput equipment, and the runtime analysis indicates that the operating time for both AFSM 100 and FSS equipment has elasticities well below 1 with respect to TPF.

Components of sorting operations' labor not related to runtime also have theoretically indeterminate elasticities with respect to the volumes of pieces sorted. The analysis of workhours suggests that the runtime elasticity is in practice a ceiling for the labor elasticity with respect to TPF for automated operations. Non-runtime activities also comprise larger shares of flat sorting costs than letter costs. Estimated labor elasticities of 0.774 and 0.804 for (respectively) AFSM 100 and FSS operations imply that the unit elasticity assumption significantly overstates estimates of marginal costs for flat sorting.

References

- Bozzo, A. Thomas (2009), "Using Operating Data to Measure Labor Input Variability and Density Economies in U.S. Postal Service Mail Processing Operations." In Crew, M.A., Kleindorfer, P.R. (eds.), *Progress in the Competitive Agenda in the Postal and Delivery Sector*. Edward Elgar.
- Bradley, Michael D., Jeffrey L. Colvin, and Marc A. Smith (1993), "Measuring Product Costs for Ratemaking: The U.S. Postal Service," in Crew, M.A., Kleindorfer, P.R. (eds.), *Regulation and the Evolving Nature of Postal and Delivery Services*. Kluwer Academic Publishers.
- Fenster, Lawrence, Diane Monaco, Edward S. Pearsall, and Spyros Xenakis (2008), "Are There Economies of Scale in Mail Processing? Getting the Answers from a Large-but-Dirty Sample." In Crew, M.A., Kleindorfer, P.R. (eds.), *Competition and Regulation in the Postal and Delivery Sector*. Edward Elgar.
- Hsiao, Cheng (1986), *Analysis of Panel Data*. Cambridge University Press.
- McCrery, Marc D. (2006), Direct Testimony of Marc D. McCrery on Behalf of the United States Postal Service, USPS-T-42 (Postal Rate Commission, Docket No. R2006-1), at https://www.prc.gov/docs/48/48698/R2006-1_Testimony_USPS-T-42.pdf (accessed May 22, 2019).

Appendix: Biographical Sketches

A. Thomas Bozzo, Ph.D. is a Vice President with Christensen Associates. Dr. Bozzo has a Bachelor of Arts degree in economics and English from the University of Delaware (1990), and a Ph.D. in economics from the University of Maryland-College Park (1998). His areas of expertise include economic cost measurement; postal, railroad, and telecommunications regulation; and applied econometrics and statistics. Since joining Christensen Associates in 1996, Dr. Bozzo has been involved with numerous projects for the Postal Service, focusing on applications of census and sample-based data, econometrics, and economic cost theory for measurement of costs for postal activities and products. He currently leads the area of practice responsible for production of clerk and mail handler cost and labor productivity data for the Cost and Revenue Analysis and Annual Compliance Reports. Dr. Bozzo was a declarant in Docket No. RM2017-3 (with Dr. Mark E. Meitzen) on price cap and performance-based regulation issues. Dr. Bozzo has presented testimony on mail processing costs in Postal Rate Commission Dockets No. R2000-1, R2005-1, and R2006-1, and testified on the In-Office Cost System (IOCS) survey instrument design in Docket No. R2006-1. For USPS OIG, Dr. Bozzo has coauthored reports on costs related to service standards and on trends in own-price demand elasticities for market dominant products. He was a primary author of the Christensen Associates 2008 study of freight railroad competition for the Surface Transportation Board, for which he led econometric analysis of the determinants of rail freight pricing. Dr. Bozzo has also been involved in numerous projects in other practice areas, including analysis of telecommunications cost models for projects related to federal and Minnesota universal service proceedings, sampling and census-based studies of electricity and natural gas demands, econometric analyses of energy efficiency programs, and a variety of litigation support projects.

Tim Huegerich, Ph.D. (University of Wisconsin–Madison, 2012) is a Senior Economist. Dr. Huegerich provides support with applied microeconomics, econometrics and statistics, data management, and writing. Dr. Huegerich also has a science background with a B.S. in physics. He is fluent in the Stata statistical software package for managing complex data sets and conducting sophisticated econometric analyses. Dr. Huegerich co-authored “Mail processing productivity, workload, and labor input variability in the PAEA era,” (with A. Thomas Bozzo) for the 2019 Rutgers Center on Research in Regulated Industries Eastern Conference. He has experience conducting economic and statistical analysis in support of intellectual property, labor, discrimination, and antitrust litigation.